

Modeling age and metallicity in globular clusters: a comparison of theoretical giant branch isochrones

T. Lejeune and R. Buser

Astron. Institut der Universität Basel, CH-4102 Binningen, Switzerland

Abstract. In view of the important contributions of red giants to the integrated light in evolutionary synthesis calculations of old stellar populations in clusters and galaxies, we provide a comparison of theoretical isochrones computed from the Padova, Geneva, and Yale evolutionary tracks, respectively. Using the most recent version of the color-calibrated library of theoretical stellar spectra by Lejeune et al. (1999), the isochrones are converted in a uniform manner to the observational color-magnitude diagrams, $(M(T_1), C - T_1)$ and $(M(I), V - I)$, and compared with observed giant branches of typical globular clusters spanning a large range of metallicities. We find that the three different isochrones of the red giant branch provide significantly different slopes and curvatures, where in general, the differences tend to be larger for metallicities decreasing below $[M/H] \sim -1$. Throughout the full metallicity range $(-2 \lesssim [M/H] \lesssim 0)$, the Yale isochrones are the only ones which show very good matches of both the observed giant branches and the associated metallicity scale derived from the color of the RGB, while the Padova isochrones exhibit significant discrepancies for low-metallicities. The effects of these differences on the integrated model colors of single stellar populations, in particular for age and metallicity determinations, are briefly addressed.

1. Introduction

Evolutionary population synthesis (EPS) is now a traditional approach to study distant galaxies from their integrated light. This technique has its foundation in stellar evolution theory which, with an appropriate library of stellar spectra, allows to predict the spectral evolution of a given stellar population. In this context, the globular clusters as single stellar populations (SSP) of old metal-deficient stars put stringent constraints on evolutionary synthesis models, which are particularly useful in investigating the effects of age and metallicity in the integrated spectro-photometric properties. In view of the important contributions of red giant branch (RGB) stars to the integrated light (up to 40–60 %) in evolutionary synthesis calculations of old stellar populations in clusters and galaxies, it is therefore important to compare the predictions of different sets of theoretical isochrones frequently used in EPS studies, such as those computed from the Padova (P), Geneva (G), and Yale (Y) evolutionary tracks.

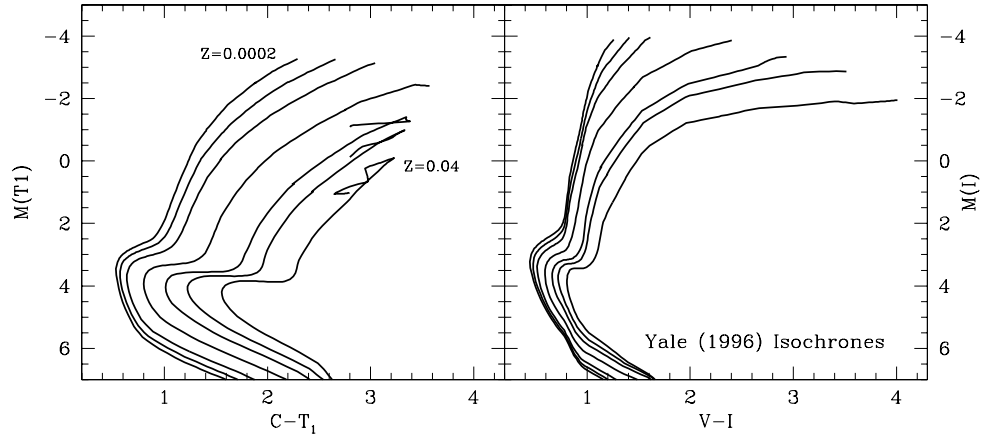


Figure 1. A comparison of the theoretical isochrones for different abundances ($Z = 0.0002$ to 0.04) in the $(M(T_1), C - T_1)$ and in the $(M(I), V - I)$ c-m diagrams (left and right panels, respectively) .

2. Theoretical color–absolute magnitude diagrams

In this work, we used the Padova (P) isochrones ($Z = 0.0001$ to 0.10) as calculated from the *Isochrone Synthesis* program of Bruzual & Charlot (see Bruzual et al. 1997), the Yale (Y) isochrones ($Z = 0.0002$ to 0.10) from Demarque et al. (1996) and the Geneva (G) isochrones ($Z = 0.001$ to 0.10) calculated by Schaerer & Lejeune (1998). All the isochrones have been converted to the observational color–magnitude (c-m) diagrams, $(M(T_1), C - T_1)$ and $(M(I), V - I)$, in a uniform manner, *i.e.*, by employing the *same* stellar library to transform the theoretical quantities ($M_{\text{bol}}, T_{\text{eff}}$) into absolute magnitudes and colors. For this purpose, we used the most recent version of the Basel stellar library (*BaSeL*) of Lejeune et al. (1999) which provides *color-calibrated* theoretical flux distributions for the largest possible range of fundamental stellar parameters, T_{eff} (2000 K to 50,000 K), $\log g$ (-1.0 to 5.5), and $[Fe/H]$ (-5.0 to $+1.0$) (for details, see Lejeune et al. 1997, 1998, 1999, and Westera et al. 1999 – these proceedings).

In Figure 1, we provide a comparison of the c-m diagrams computed from the Y-isochrones in the Washington and in the Johnson-Cousins systems, $(M(T_1), C - T_1)$ and $(M(I), V - I)$, respectively. Both the position and the curvature of the RGB are very sensitive to the metallicity, as already noticed in the empirical studies by Da Costa & Armandroff (1990, hereafter DCA90) for $V - I$, and by Geisler & Sarajedini (1999, [GS99]) for $C - T_1$. The larger separation of the isochrones in $C - T_1$ confirms the superior metallicity sensitivity of the Washington system, in particular at low-metallicities. Note also that the observed *near-constancy of the absolute magnitude*, $M(I)$ or $M(T_1)$, of the RGB-tip, is confirmed by theory for $Z \lesssim 0.04$ ($[M/H] \lesssim -0.5$) to within a dispersion $\sigma(M) \lesssim 1$ mag – supporting the use of this property in Galactic and extragalactic distance determinations.

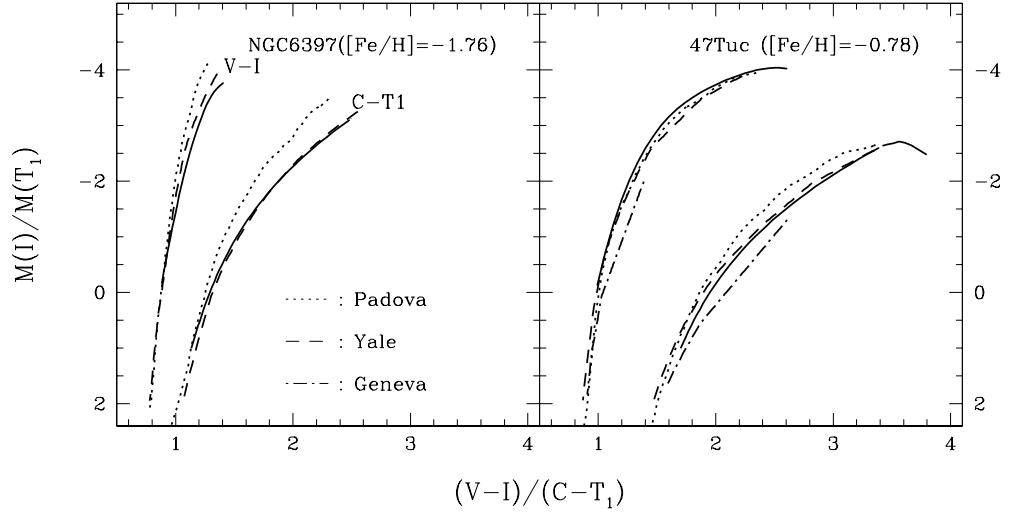


Figure 2. Theoretical RGBs compared to standard-observed RGBs (solid lines) for two clusters given by DCA90 in $M(I)$ vs. $V - I$ and by GS99 in $M(T_1)$ vs. $C - T_1$. The isochrones have been interpolated graphically (linearly in $[\text{Fe}/\text{H}]$) at the metallicity of the cluster (as given by Caretta & Gratton, 1997), assuming a typical age of 14 Gyr. Enhancement from the α -elements, when known for the cluster, has been taken into account following the prescriptions of Salaris et al. (1993). Note the large discrepancy in the upper part of the RGB between the P-models and the observations for the metal-poor globular cluster NGC 6357.

3. Comparisons with observed giant branches

In Figure 2, theoretical RGBs from the P-, the Y- and the G-isochrones at a typical age of 14 Gyr are compared with the observed *standard* giant branches of the globular clusters NGC 6397 and 47 Tuc defined by DCA90 in $V - I$ and by GS99 in $C - T_1$. Systematic differences exist between the theoretical isochrones and the observed giant branches, and between the models themselves. While the P- isochrones reproduce very well the RGB of 47 Tuc, large discrepancies are found for NGC 6357 ($[\text{Fe}/\text{H}] = -1.76$), both in $V - I$ and $C - T_1$. More generally, our tests with other clusters (Lejeune & Buser 1999) indicate that the P-models provide reliable theoretical RGBs for metal-rich and intermediate-metallicity globular clusters, while they become systematically too blue for $[M/H] \lesssim -1.4$. This is particularly true in Washington photometry with color differences, $\Delta(C - T_1)$, at the RGB-tip increasing up to 0.4 mag with decreasing $[M/H]$. At the opposite, the Geneva models appear slightly too red when compared to the different cluster branches. Our comparisons show in particular that, over the whole range of metallicities ($\sim -2 < [M/H] < 0$) and within an age range between 8 and 17 Gyr, the best agreement is provided by the Y-isochrones, which reproduce very well the position and the curvature of the observed standard

giant branches of DCA90 and GS99, along with the empirical metallicity scales derived from the color of the RGB at a fixed absolute magnitude (Lejeune & Buser 1999).

4. Conclusions

In view of their use in old stellar population studies, we have compared the predictions of Padova, the Yale and the Geneva sets of theoretical isochrones with recent observations of globular cluster giant branches. We find in particular that, at a given typical old age of 14 Gyr, the 3 different isochrones of the RGB provide significantly different slopes and curvatures, with differences increasing for metallicities decreasing below $[M/H] \lesssim -1$. The Y-isochrones are the only ones which show excellent agreement throughout the full range of metallicities with observed globular cluster giant-branch templates in both photometric systems. The P-isochrones agree well with observations only at the higher metallicities, while for the lower metallicities they become generally too blue, by up to -0.4 mag at the tip of the RGB. Finally, the G-isochrones are systematically redder than the observations. As all the theoretical isochrones have been converted in an uniform manner by employing the same stellar library, such discrepancies must likely be attributed to differences in the physics employed in the different calculations of the stellar evolutionary tracks.

The influence of such differences on the integrated colors predicted by stellar population models, which can lead in particular to systematic uncertainties in age (~ 2 – 3 Gyr) and/or in metallicity (~ 0.2 – 0.3 dex), will be discussed in a forthcoming paper (Lejeune & Buser 1999).

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